

The *invisible wall* project on problem solving processes: Concepts and methods of interpretive work with high-resolution data

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The project *pupils work on problems with a goal which cannot be reached* ("*invisible wall project*") analyses problem solving processes of children in grades 3-4 and 7-8. So far, we have described basic components of problem solving abilities by using interpretive methods. We now want to apply statistical methods, e.g., for comparing abilities of younger/older children. Consequently, we have complemented the qualitative interpretive methods by quantitative methods. The paper describes the methodological background of both sides of the project.

Introduction: The *invisible wall* project and its methodological problems

Since 1992 I have been working - together with several groups of student teachers - on the analysis of problem solving processes. We focus on components of problem solving ability which are *not* subject of mathematics lessons. As a consequence, we did not deal with word problems and other Aclassical problems@. The central idea of our research was to use sets of tasks which are *unsolvable* which means they have a goal which can not be reached. The unsolvability, however, is of a kind which can be understood even by younger children (e.g.: try to find exactly 4 different numbers out of the set {1, 2, 3, 4, 5} which give the sum 9; see another example on the next page). Subsequently, we shall use the term *impossible task* as well. Impossible tasks are used for several reasons:

- The impossibility of the task acts as an **Ainvisible wall@** for the pupils' actions: the pupil tries to solve the task, gets stuck ("bounces against the invisible wall"), and tries a different way to do it. As a consequence, we get information out of the pupils' attempts to solve the task.
- *The tasks stimulate natural reasoning behavior*: the pupil looks for reasons "why he/she cannot do it ..."!
- Because the goal of the tasks cannot be reached, they cannot be solved by chance. They are not too simple even for pupils who are good in mathematics. Consequently, a puzzle which is not solvable can have a far simpler structure than one which can be solved. This is *good for the transcription of problem solving processes*.

In the first part of the project we have identified elementary components of problem solving behaviour which are used by younger children (the methods and some of the results are described in STEIN 1997). The search for those components was organized as search for noticeable patterns in the subject=s behaviour.

In the present stage of the project we try to describe profiles of problem solving processes. As will be discussed later, our approach is *qualitative-interpretative*.

With the help of the above mentioned grant, we have protocolled and fully transcribed approximately 160 interviews with pupils of grades 3-4 and grades 7-8. This material should be open to analysis by *quantitative* methods.

Qualitative methods have a high demand of manpower (for transcription and inter-

pretation). So, collecting large numbers of quantitative material for making it accessible to statistical analysis demands careful considerations:

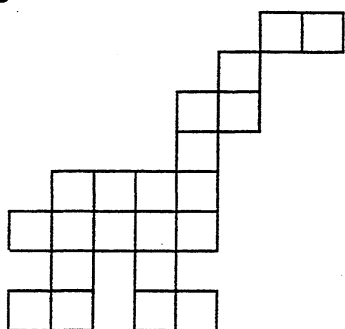
- Since transcription is time consuming and causes high expenses, transcription techniques should be not more complex than necessary. On the other hand, transcripts should comprise enough information for substantial interpretation.
- Editing the collected material for statistical analysis should not wipe off the interpretive features of the research.

This paper focuses on the solution of the *methodological problems* described above.

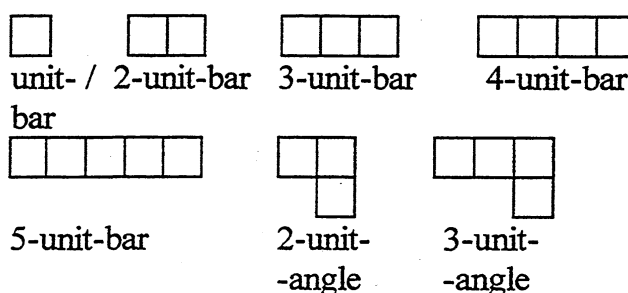
The tasks

We work with a range of different puzzles. In this paper we concentrate on the following puzzle:

"Giraffe"



The puzzle shall be filled exactly with the following parts (each is given once).



Control of Complexity as criterion for the choice of document type

One main *technical* problem in designing an interpretative study lies in *controlling the complexity* of the documents which are to be analysed.

Videotapes are of very high complexity. The stored information bears a manifold of different aspects. If a researcher gives a videotape to different groups of interpreters he/she will find that they focus on different aspects. Even if he/she defines strictly the aspects under consideration he/she will still find that different groups will use different bits of information to back their interpretation: they may focus on body language, on intonation, on mimics, and so on. Even worse: the researcher cannot control subconscious effects of body language etc. on the interpreters.

As a consequence, videotapes have no possibility of controlling their complexity. Audiotapes have the same disadvantages as videotapes.

Transcripts show a well defined part of the original video- or audiotape in written form. Writing a transcript, the researcher has full control over the complexity of his material. As *methodological consequence*, our analyses are based on transcripts.

Transcription

Methods of transcription

Within any project of interpretive research, transcription has to follow well defined standards. Any report on interpretive research has to give full information of the transcription rules.

Under the aspect of *control of complexity* the researcher has to decide carefully what aspects of the tape shall be written down. We find different stages in complexity:

- *Speech transcripts* contain at least an exact record of the words spoken.
- *Action transcripts* give additional information about actions performed by the pupils and normally contain information about speech as well. Special care has to be taken to define precisely what actions are transcribed, what actions will not be transcribed. The transcribers should stick exactly to those rules.

Methodological decisions of the project

Since we work with younger pupils, all our tasks use material which can be manipulated by the children. In our research we see pupils act (and react), and try to describe and classify the observed patterns in the problem solving processes.

The "spoken word" does *not* play a big role in our research, since pupils do not speak very much during their work (we do not encourage pupils to "think loud" since this would interfere the process of solving the task). For transcription of the spoken word we chose not to simplify or correct sentences. We measured *breaks* in seconds and included this in the transcript, for instance by [...] for a three second break, [10 sec] for a ten second break. Passages which could not be understood were measured and included in the transcript, for instance by (...) for 4 seconds of murmur which could not be understood.

Since the processes observed consist of actions, we use *action transcripts*.

It is useful to distinguish between *hard rules* and *soft rules*. We transcribe *every single action which ends with a puzzle piece laid down and everything spoken out loudly* (hard rule). Transcribers included information about body language or shown emotions if they considered them important (soft rule).

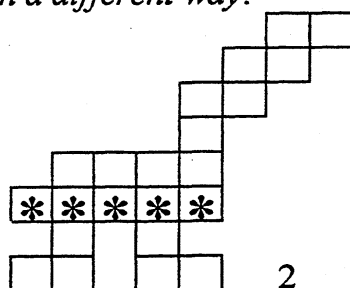
The inclusion of time-information is essential for action transcripts. We note - for each action transcribed - the exact time of its beginning and its end. Having exact information about time, the interpreters can consider the speed of action.

The following example (2.05 means: we start after 2 minutes and 5 seconds of work) shows two pupils working on our puzzle. Transcription is as viewed "from above". That means, the pupils are sitting at a table with the puzzle between them. Text on the left (right) side refers to the pupil sitting left (right). Actions which are written below other actions happened later.

Interviewer: *And if you start in a different way?*

No, this has to be put there.
points to the 5-unit-bar

points to* *No, the 5-unit-bar
must be placed there.*
It has to be placed here!
points to*

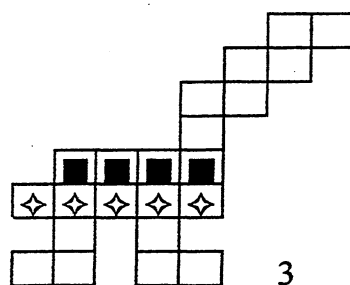


No, let us look everywhere 2.05
takes the 5-unit-bar into the hand

moves the 5-unit-bar over the
puzzle

puts down the 4-unit-bar
The 4-unit-bar has to be placed here

But there are no other possibilities for it.

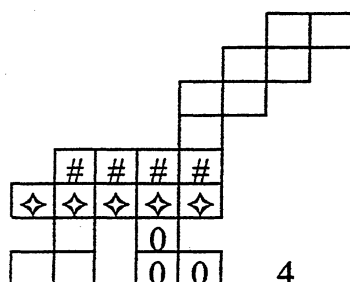


puts down the 5-unit-bar

No, that's not the only place.
removes the 4-unit-bar

2.23

points to the 4-unit-bar
This has to be placed there.
Points to #. We don't have possibility for this piece.



No, wait, let's first fill in this place.
puts down the 2-unit-angle
For instance.

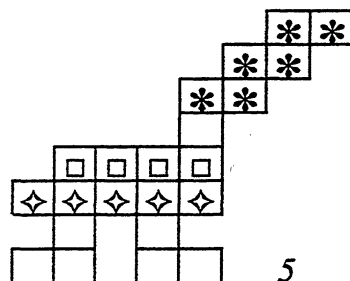
puts the 4-unit-bar to #

2.40

removes the 2-unit-angle

takes 3-unit-bar from his partner /holds it over*
this is not possible.

puts the 3-unit-bar away
No, this can not be done.



holds 3-unit-bar in his hand

takes 4-unit-bar
and 5-unit-bar away.

It must be possible to solve it

Communicability of documents

Whatever the chosen type of transcript is, the researcher has to decide about the *resolution* of transcription. High-resolution-transcripts may contain valuable additional information about body language, intonation and so on. Especially in the case of high resolution action transcripts the researcher will find that they may not be communicable to anyone outside his/her research group. Such transcripts may be useful - but for *internal use only*. If high resolution is necessary for the aims of the study, the researcher should use low resolution versions of his transcripts for publication of results. Under the aspect of communicability, video- or audiotapes are not suitable documents to work with.

As the example above shows, we take care to keep our transcripts communicable to others. (Though written with a different focus, L. Richardson's paper on *writing* (Richardson 1994) shows the same interest in communicability.)

Interpretation of documents

Problems of interpretive work

Any bit of the analysed document can be seen under different aspects. Any remark or action can have a large *variety of meanings*. This is the reason why we speak of *interpreting* documents, and do not use terms like *classifying* or *grading*.

The applied technique of interpretation depends on research interest and theoretical background and should be described carefully. Though there are nearly as many interpretation procedures as there are research projects, some standards are common (e.g.: interpretations are done by *groups of interpreters*; *indicators* should be used to support interpretations, esp. in the case of conflicting opinions about).

Methodological decisions of the project

In our project, the behavior of the children is analysed under a broad range of aspects. In many cases there will be more than one interpretation of the same behaviour. The same action may be interpreted, for instance, as a consequence of a social conflict between the two children, or may be seen as influenced by gestalt operations or be understood as guided by explicit use of heuristic strategies. The variety of meanings is a very important reason to follow the standard of *working in groups* when interpreting a given document, since only a group of interpreters has the chance of avoiding one-dimensional interpretation.

If a group of interpreters intends to interpret a part of an episode unambiguously, they need *indicators*. Indicators may be *weak* or *strong* with respect to the amount of ambiguity they dissolve.

In our project, we want to see whether a pupil has "understood" the unsolvability of the task. A weak indicator for this is the plain remark "*This puzzle is not solvable*". This remark *may* be a sign of a deeper insight, but as well it may just mean "*The puzzle is not solvable in the way we started to do it*".

Strong indicators for insight in unsolvability are (among others)

- refusal to continue work when asked to start a new attempt in solving the puzzle; o
- explicitly contradicting the other pupils' opinion that the puzzle is solvable.

Structuring documents

The problem of finding a structure

Very often we shall face the problem that the source document is too long for getting a full overview of its content. It will be helpful then to structure it by dividing it into smaller passages which are called *episodes* (Krummheuer 1992). Episodes may be named. They may be split into *phases* (Voigt 1984, p. 128).

When working with a full transcription of the source document, episodes may be used to give a short summary of the transcript.

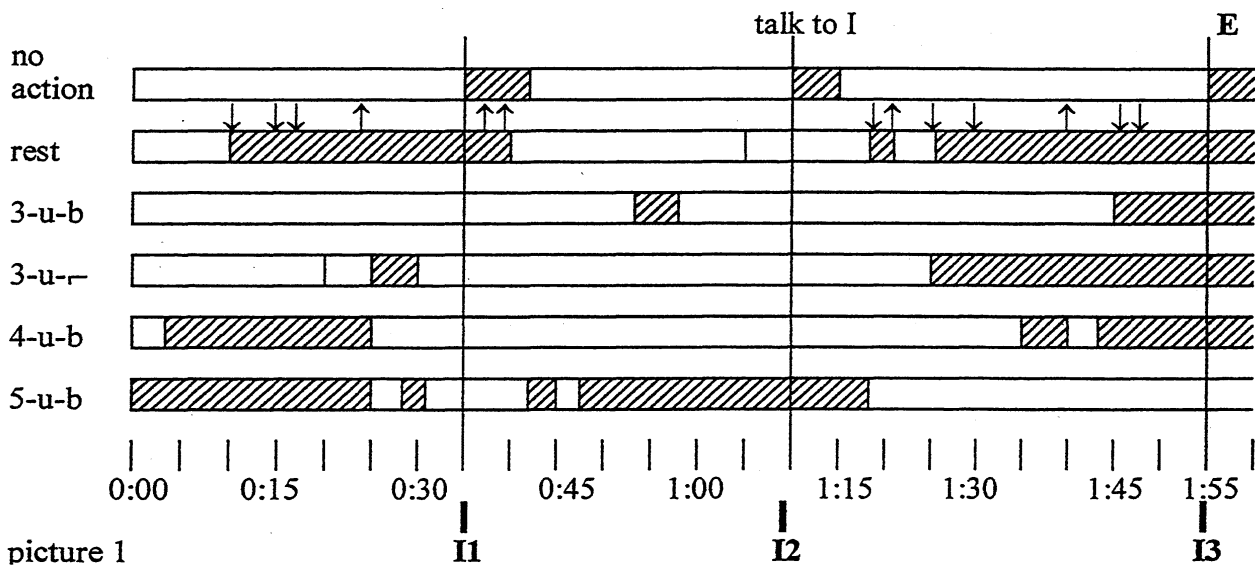
A so called *episode plan* (Wollring 1994) may as well be written *before* doing anything else. This episode plan can be used for describing the content of the whole document. Under the aspect of communicability, it is a valuable information for the reader of a report who may use it to locate the position of the transcribed episodes within the basis document.

Methodological decisions of the project

Action profiles: The example above shows that action transcripts consume lots of space. A 5 minute interview easily needs 20 pages of transcription. In our project, neither of these "episode approaches" for structuring the transcripts is useful: having a high number of transcribed interviews, we have to use coders for structuring the documents. Since this coding has to be reliable for later use in statistical analyses, the built-in ambiguity of the interpretive approach of phases and episodes is not helpful in our case.

The first answer to this problem are *action profiles*. In the case of our puzzle, we have "time bars" to code when the 5-unit-bar resp. the 4-unit-bar resp. the 3-unit-angle resp. the 3-unit-bar is laid down, and how long it stays on the puzzle. Another bar codes actions with the rest of the puzzle pieces. In the last case, arrows \downarrow \uparrow denote the moment when one of those pieces was laid down resp. removed from the puzzle.

I1, I2, I3 means questions of the interviewer, following the standardised design. The following picture 1 shows the (for reasons of communicability simplified) action profile of two pupils in grade 4. The explanation phase (marked **E**) is shown abridged. It begins at 1:55 and lasts until 2:10 with the pieces lying on the puzzle as shown.



To help the reader understanding the profile, we comment the first 35 seconds of the profile:

The 5-unit-bar is laid down as soon as the work starts. It remains on the puzzle until 0:25. App. at 0:02 the 4-unit-bar is laid down. This piece remains on the puzzle until 0:25. After some hesitation, from 0:10 on the pupils start working with small pieces. (Normally this will be "filling up the head or the feet"). At 0:25, the 4-unit-bar and the 5-unit-bar are removed, the 3-unit-angle is laid down and remains on the puzzle for 5 seconds. Shortly before 0:30, the 5-unit-bar is laid down again. Then, the 3-unit-angle and the 5-unit-bar are both removed. There is no action from 0:30 to 0:35. Some small pieces are still lying on the puzzle. At 0:35 we find the first intervention of the interviewer.

We see that the combination 5-unit-bar/4-unit-bar - which is essential for understanding why the task is impossible - was only found at the beginning of the interview. Such problem solving processes are called *decreasing*. Normally, in such interviews children do not find good explanations for the impossibility of the task.

Structures of action profiles: It is quite obvious that it is not difficult to get highly reliable codings of action profiles. We are now able (though we can not do it in this paper) to describe different types of such profiles. For instance, the example above shows a decreasing profile. If the 5-unit-bar is lying on the puzzle during the last phase of the solving process only, we will call the profile increasing.

Using this classification, we will be able to use statistical methods for describing differences between problem solving abilities of younger pupils compared with pupils of grades 7 to 9. We might ask, for instance: Do older pupils produce significantly more increasing profiles than younger pupils?

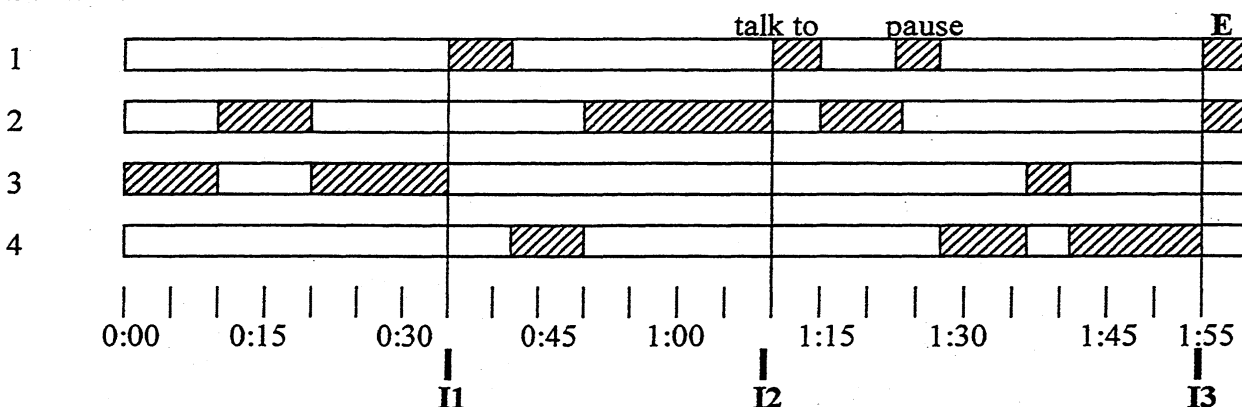
On the other hand, our action profiles will have to be "read" and "understood". We may ask, for instance: *increasing profiles end with the 5-unit-bar "in the right place". Is this in all cases an indicator for a "good" problem solving process?* So, in the long end, we will have to return to interpretive work. How this can be done, will be shown in the next sections.

Interpretation profiles: As in the case of action profiles, we work with time bars. Now, however, the bars stand for a qualitative interpretive analysis of the problem solving process. With our puzzles, we use the following categories:

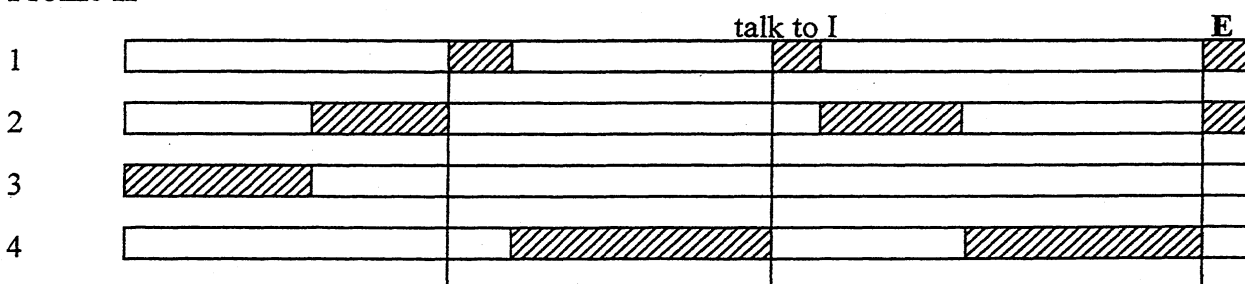
(1) No action; (2) Sequences of *gestalt* reactions (there is some similarity to Davis/Mc Knight's notion of *visually moderated sequences*); (3) Sequences guided by logical or analytical considerations; (4) Other systematic behavior (trying to fill the puzzle, beginning at one end of it without leaving gaps, for instance).

The result is called *interpretation profile*. In the following, we see two different interpretation profiles for the action profile of the preceding page:

Profile I



Profile II



Under the aspect of ambiguity of interpretation, the interpreters tried to develop for the same interview *two* interpretation profiles which should differ as much as possible. We call this method *divergent coding*.

Though rather different, the interpretation profiles of the above process have some features in common:

- Both interpreters accept a procedure with a logical structure only at the beginning of the interview. But disagree about the length of it (Profile I: 10";

Profile II: 23"). Anyway, we can conclude, that the "logical action" at the beginning of the work will not have been caused by some careful consideration.

- Both interpreters see some "other systematic" behavior at the end of the interview.

Altogether, the interpretation profiles give a strong feeling that the pupils may have started with "a good idea", but if it was so, this "got lost" afterwards. They did some trial end error in the middle phase - about the quality of the actions the coders have different opinions - and ended their work with no real insight in the impossibility, but were unsuccessfully trying to fill the puzzle up (not surprisingly, the action profile shows many actions with the small pieces). The explanation is characteristic: "It can't be done because there are some pieces wrong".

Conclusion

Our research interest led us to develop a high resolution transcription technique: *action transcripts*. Understanding the problem solving processes and answering the question whether the pupil "understood" the impossibility of reaching the goal, needs *interpretive methods* which bear in mind that nearly every action of the pupils can have more than one "meaning".

The basic methodological problem of our research is caused by the high number of interviews. High resolution transcripts are very long. We have to compress the information contained in them to make it accessible to statistical methods. On the other hand, we do not want to lose essential aspects of interpretive analysis of the interviews.

Our solution to the problem described follows for some distance a design which seems to be characteristic for interpretive research with large numbers of data: parallel or additional to interpretation processes there are methods applied for coding the data in a more efficient way. (For instance, the interpretive analysis of school lessons may be complemented by *Bellack coding*). Having standardised and analysed our data by using and categorizing our *action profiles*, we leave the standard pathway in the long end by adding a new element: *divergent coding* brings back the ambiguity of interpretive work and can add useful information to otherwise rather dry statistical data.

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